

1       We claim:

2  
3       1) A power combiner having:

4       a central axis about which is disposed a plurality of  
5       cylindrical feed waveguides, each said feed waveguide  
6       having a radius, an input port and a launching port, all  
7       centered on a feed waveguide axis, said launching port  
8       including a cylindrical section formed by sweeping a line  
9       of length  $L_{\text{launch}}$  and said radius through an included angle  
10       $\alpha$ ;

11      a plurality of focusing reflectors, one for each said  
12      feed waveguide, each said focusing reflector centered on  
13      said feed waveguide axis;

14      a cylindrical final waveguide coaxial to said central  
15      axis and collecting power reflected by each said focusing  
16      reflector.

17  
18      2) The power combiner of claim 1 where said feed  
19      waveguide axis is parallel to said central axis.

20  
21      3) The power combiner of claim 1 where each said feed  
22      waveguide radius is equal to each other said feed waveguide  
23      radius.

1           4) The power combiner of claim 1 where at least one  
2 said feed waveguide radius is different from any other said  
3 feed waveguide radius.

4  
5           5) The power combiner of claim 1 where said feed  
6 waveguide launching port cylindrical section is convex to  
7 said central axis, and said corresponding reflector is  
8 concave to said central axis.

9  
10          6) The power combiner of claim 5 where said feed  
11 waveguide cylindrical section and said reflector are  
12 symmetrically arranged with respect to a plane from said  
13 central axis to said feed guide center axis.

14  
15          7) The power combiner of claim 5 where said feed  
16 waveguide cylindrical section and said reflector are  
17 asymmetrically arranged with respect to a plane from said  
18 central axis to said feed guide center axis.

19  
20          8) The power combiner of claim 1 where said feed guide  
21 launching port cylindrical section is concave to said  
22 central axis, and said corresponding reflector is convex to  
23 said central axis.

1           9) The power combiner of claim 8 where said feed  
2 waveguide cylindrical section and said reflector are  
3 symmetrically arranged with respect to a plane from said  
4 central axis to said feed guide center axis.

5  
6           10) The power combiner of claim 8 where said feed  
7 waveguide cylindrical section and said reflector are  
8 asymmetrically arranged with respect to a plane from said  
9 central axis to said feed guide center axis.

10  
11           11) The power combiner of claim 1 where said launch  
12 port has a length  $L_{\text{launch}}$ , where

$$L_{\text{launch}} = 2\pi R_{\text{feed}} \{ k_{\text{par}} \sqrt{1 - (m/X_{mn})^2} \} / \{ k_{\text{perp}} \cos^{-1}(m/X_{mn}) \}$$

14 where

15  $k_{\text{par}}$  is the parallel, or axial wave number

16  $R_{\text{feed}}$  is said radius of said feed waveguide

17  $m$  is the azimuthal index of the mode in said feed

18 waveguide

19  $n$  is the radial index of the mode in said feed

20 waveguide

21  $X_{mn}$  is the eigenvalue of the mode

22  $K_{\text{perp}}$  is the perpendicular wave number.

23

1           12) The power combiner of claim 1 where said launch  
2 port included angle is between 160 and 200 degrees.

3  
4           13) The power combiner of claim 1 where said reflector  
5 is formed by a curve extruded along said central axis, said  
6 reflector curve comprising a locus of points.

7  
8           14) The power combiner of claim 13 where said locus of  
9 points satisfies the following criteria, where a first  
10 focus is located on said central axis, and a second focus  
11 is located at the center of said feed waveguide:

12           a) the sum of the path length from said first focus to  
13 any given locus point and from said given locus point to  
14 said second focus point is a constant,

15           b) at each locus point, an intersection point is  
16 defined by the intersection of said locus point, a tangent  
17 line which is tangent to said reflector curve at said locus  
18 point, and a perpendicular line which is perpendicular to  
19 said tangent line at said locus point, said perpendicular  
20 line bisecting the angle formed by a line from said  
21 intersection point to said first focus and said  
22 intersection point to said second focus.

1           15) The power combiner of claim 1 where said plurality  
2 comprises k feed waveguides and k reflectors, and the  
3 angular extent of each said reflector is  $360/k$  degrees with  
4 respect to said central axis.

5  
6           16) The power combiner of claim 1 where each said  
7 input waveguide is coupled to a source of symmetric  
8 traveling wave power, said input power traveling through  
9 each feed waveguide, reflecting from said reflector and  
10 collected in said final waveguide.

11  
12           17) A power splitter comprising the power combiner of  
13 claim 1 where said final waveguide is coupled to a source  
14 of traveling wave power, said traveling wave power exiting  
15 said final waveguide at a reflector end, reflecting from  
16 each said reflector and thereafter coupling to each said  
17 feed waveguide launch port, delivering traveling wave power  
18 to each said input port.

19  
20           18) The power splitter of claim 18 where the power  
21 applied to said final waveguide splits uniformly between  
22 each said feed waveguide input port.

1        19) The power splitter of claim 18 where the power  
2        applied to said final waveguide splits unevenly between at  
3        least one said feed waveguide and any other said feed  
4        waveguide.

5  
6        20) A power combiner having:  
7        a central axis about which is disposed a plurality k  
8        of cylindrical feed waveguides, each said feed waveguide  
9        having a radius, an input port and a launching port, all  
10       centered on a feed waveguide axis, said launching port  
11       including a cylindrical helix;

12       a plurality k of focusing reflectors, one for each  
13       said feed waveguide, each said focusing reflector centered  
14       on said feed waveguide axis;

15       a final waveguide coaxial to said central axis and  
16       collecting power reflected by each said focusing reflector  
17       with a proximal final waveguide reflector port, said final  
18       waveguide reflector port including a multi-cut helix having  
19       k cuts.

20  
21       21) The power combiner of claim 20 where  
22        $(1/\pi) \arccos (m/X_{mn})$  is not an integer, when  
23       said m = azimuthal wave number  
24       said m = radial wave number

1        said  $X_{mn}$  = the eigenvalue of the mode.

2

3        22) The power combiner of claim 20 where said feed  
4        guide launch port helical section is formed by sweeping a  
5        line of length  $L_{\text{feedlaunch}} = \theta * L_{\text{feedhelix}} / 2\pi$  at said radius from  
6        and parallel to said feed guide axis, where  $0 \leq \theta \leq 2\pi$  and  
7         $\theta$  is the angle in radians about said feed waveguide axis  
8        and said  $L_{\text{feedhelix}}$  is the depth of the helical cut.

9

10       23) The power combiner of claim 20 where said final  
11       waveguide reflector port multi-cut helix is formed by the  
12       surface of rotation formed by sweeping a line of varying  
13       length  $L_{\text{finalmulticut}}$  at said radius from said central guide  
14       axis about an angle  $\theta$ ;

15       thereafter joining end-for-end  $k$  said surfaces of  
16       rotation to form a cylindrical solid having  $k$  helical cuts

17       where

18        $L_{\text{finalmulticut}} =$

19        $(L_c/k) * (\theta / (k * 2 * \pi))$  for  $0 \leq \theta \leq 2 * \pi / k$

20        $L_c = 2\pi R_{\text{final}} \{ k_{\text{par}} \sqrt{1 - (p/X_{pq})^2} \} / \{ k_{\text{perp}} \cos^{-1}(p/X_{pq}) \}$

21        $(L_c/k)$  is the multicut depth

22        $k_{\text{par}}$  is the parallel, or axial wave number

23        $R_{\text{final}}$  is the radius of the final waveguide

1        p is the azimuthal index of the mode in said final  
2 waveguide

3        q is the radial index of the mode in said final  
4 waveguide

5         $X_{pq}$  is the eigenvalue of the mode

6         $K_{\text{perp}}$  is the perpendicular wave number

7        k is the number of multicuts

8

9

10       24) The power combiner of claim 20 where said feed  
11 waveguide axis is parallel to said central axis.

12

13       25) The power combiner of claim 20 where each said  
14 feed waveguide radius is equal to each other said feed  
15 waveguide radius.

16

17       26) The power combiner of claim 20 where at least one  
18 said feed waveguide radius is different from any other said  
19 feed waveguide radius.

20

21       27) The power combiner of claim 20 where each said  
22 feed waveguide helical section angle  $\theta = 0$  is uniformly  
23 offset with respect to a plane from said central axis to  
24 said feed guide center axis.



1  
2        28) The power combiner of claim 20 where each said  
3 feed waveguide helical section angle  $\theta = 0$  is not uniformly  
4 offset with respect to a plane from said central axis to  
5 said feed guide center axis.

6  
7        29) The power combiner of claim 20 where said feed  
8 guide helical launch port has a helical cut depth  $L_{\text{feedlaunch}}$   
9  
10 where

11         $L_{\text{feedlaunch}} = LC$

12         $LC = 2\pi R_{\text{feed}} \{ k_{\text{par}} \sqrt{1 - (m/X_{mn})^2} \} / \{ k_{\text{perp}} \cos^{-1}(m/X_{mn}) \}$

13         $R_{\text{feed}}$  is said feed guide radius

14         $k_{\text{par}}$  is the parallel, or axial wave number

15         $m$  is the azimuthal index of the mode in said feed

16 guide

17         $n$  is the radial index of the mode in said feed guide

18         $X_{mn}$  is the eigenvalue of the mode

19         $K_{\text{perp}}$  is the perpendicular wave number.

20  
21        30) The power combiner of claim 20 where said final  
22 guide multicut port has a helical multi-cut depth

23         $L_{\text{finalmulticut}} = 2\pi \{ k_{\text{par}} \sqrt{1 - (p/X_{pq})^2} \} / \{ k_{\text{perp}} \cos^{-1}(p/X_{pq}) \}$

24 where

1         $k_{\text{par}}$  is the parallel, or axial wave number  
2         $p$  is the azimuthal index of the mode in said final  
3 guide  
4         $q$  is the radial index of the mode in said final guide  
5         $X_{pq}$  is the eigenvalue of the mode  
6         $K_{\text{perp}}$  is the perpendicular wave number.  
7

8        31) The power combiner of claim 20 where said  
9 reflector is formed by a curve extruded along said central  
10 axis, said reflector curve comprising a locus of points.  
11

12        32) The power combiner of claim 20 where said locus of  
13 points satisfies the following criteria for each given  
14 locus point:

15        where each said feed waveguide has a circular feed  
16 caustic and a feed caustic phase front, and said final  
17 guide has a circular final caustic and a final caustic  
18 phase front, for each point on said locus, a first line  
19 segment starting from said locus point, touching said feed  
20 caustic and ending on said feed caustic phase front, and a  
21 second line segment starting on said locus point, touching  
22 said final caustic and ending on said final caustic phase  
23 front:

1       a) the path length of said first line segment added to  
2       said second line segment is a constant,

3       b) at each said locus point, an intersection point is  
4       defined by the intersection of said locus point and a line  
5       which is tangent to said reflector curve at said locus  
6       point, and a perpendicular line which is perpendicular to  
7       said tangent line at said locus point, said perpendicular  
8       line bisecting the angle formed by said first line segment  
9       and said second line segment.

10

11       33) The power combiner of claim 20 where said  
12       plurality comprises k feed waveguides and k reflectors, and  
13       the angular extent of each said reflector about said  
14       central axis is  $360/k$  degrees.

15

16       34) The power combiner of claim 20 where each said  
17       input waveguide is coupled to a source of asymmetric  
18       traveling wave power, said input power traveling through  
19       each feed waveguide, reflecting from said reflector and  
20       collected in said final waveguide.

21

22       35) A power splitter comprising the power combiner of  
23       claim 20 where said final waveguide is coupled to a source  
24       of traveling wave power, said traveling wave power exiting

1 said final waveguide, reflecting from each said reflector  
2 and thereafter coupling to each said feed waveguide launch  
3 port, and delivering traveling wave power to each said  
4 input port.

5

6 36) The power splitter of claim 34 where the power  
7 applied to said final waveguide splits evenly between each  
8 said feed waveguide input port.

9

10 37) The power splitter of claim 34 where the power  
11 applied to said final waveguide splits unevenly between at  
12 least one said feed waveguide and any other said feed  
13 waveguide.

14

15 38) A power combiner having:

16 a central axis about which is disposed a plurality k  
17 of cylindrical feed waveguides, each said feed waveguide  
18 having a radius, an input port and a launching port, all  
19 centered on a feed waveguide axis, said launching port  
20 including a cylindrical helix;

21 a plurality k of focusing reflectors, one for each  
22 said feed waveguide, each said focusing reflector centered  
23 on said feed waveguide axis;

1        a final waveguide coaxial to said central axis and  
2        collecting power reflected by each said focusing reflector  
3        with a proximal final waveguide reflector port.

4  
5        39) The power combiner of claim 38 where  
6         $(1/\pi) \arccos(p/X_{pq})$  is an integer, when  
7        said  $p$  = azimuthal wave number  
8        said  $q$  = radial wave number  
9        said  $X_{pq}$  = the eigenvalue of the mode.

10  
11        40) The power combiner of claim 38 where said feed  
12        guide launch port helical section is formed by sweeping a  
13        line of length  $L_{\text{feedlaunch}} = \theta * L_{\text{launch}} / 2 * \pi$  at said radius from  
14        and parallel to said feed guide axis, where  $\theta$  is the angle  
15        in radians about said feed waveguide axis and said  $L_{\text{launch}}$  is  
16        the length of the helical cut.

17  
18        41) The power combiner of claim 38 where said final  
19        waveguide is a cylinder.

20  
21        42) The power combiner of claim 38 where said feed  
22        waveguide axis is parallel to said central axis.

23

1           43) The power combiner of claim 38 where each said  
2 feed waveguide radius is equal to each other said feed  
3 waveguide radius.

4  
5           44) The power combiner of claim 38 where at least one  
6 said feed waveguide radius is different from any other said  
7 feed waveguide radius.

8  
9           45) The power combiner of claim 38 where each said  
10 feed waveguide helical section angle  $\theta = 0$  is uniformly  
11 offset with respect to a plane from said central axis to  
12 said feed guide center axis.

13  
14           46) The power combiner of claim 38 where each said  
15 feed waveguide helical section angle  $\theta = 0$  is not uniformly  
16 offset with respect to a plane from said central axis to  
17 said feed guide center axis.

18  
19           47) The power combiner of claim 38 where said feed  
20 guide helical launch port has a helical cut depth

21            $L_{\text{feedlaunch}} = 2\pi \{ k_{\text{par}} \sqrt{1 - (m/X_{mn})^2} \} / \{ k_{\text{perp}} \cos^{-1}(m/X_{mn}) \}$

22 where

23            $k_{\text{par}}$  is the parallel, or axial wave number

1        m is the azimuthal index of the mode in said feed  
 2    guide  
 3        n is the radial index of the mode in said feed guide  
 4         $X_{mn}$  is the eigenvalue of the mode  
 5         $K_{\text{perp}}$  is the perpendicular wave number.

6

7        48) The power combiner of claim 38 where said final  
 8    guide multicut port has a helical multi-cut depth  $L_{\text{finalmulticut}}$   
 9     $= 2\pi \{ k_{\text{par}} \sqrt{1 - (p/X_{pq})^2} \} / \{ k_{\text{perp}} \cos^{-1}(p/X_{pq}) \}$

10    where

11         $k_{\text{par}}$  is the parallel, or axial wave number  
 12        p is the azimuthal index of the mode in said final  
 13    guide  
 14        q is the radial index of the mode in said final guide  
 15         $X_{mn}$  is the eigenvalue of the mode  
 16         $K_{\text{perp}}$  is the perpendicular wave number.

17

18

19        49) The power combiner of claim 38 where said  
 20    reflector is formed by a curve extruded along said central  
 21    axis, said reflector curve comprising a locus of points.

22

1           50) The power combiner of claim 38 where said locus of  
2 points satisfies the following criteria for each given  
3 locus point:

4           where each said feed waveguide has a circular feed  
5 caustic and a feed caustic phase front, and said final  
6 guide has a circular final caustic and a final caustic  
7 phase front, for each point on said locus, a first line  
8 segment starting from said locus point, touching said feed  
9 caustic and ending on said feed caustic phase front, and a  
10 second line segment starting on said locus point, touching  
11 said final caustic and ending on said final caustic phase  
12 front:

13  
14           a) the path length of said first line segment added to  
15 said second line segment is a constant,

16           b) at each said locus point, an intersection point is  
17 defined by the intersection of said locus point and a line  
18 which is tangent to said reflector curve at said locus  
19 point, and a perpendicular line which is perpendicular to  
20 said tangent line at said locus point, said perpendicular  
21 line bisecting the angle formed by said first line segment  
22 and said second line segment.

23



1           51) The power combiner of claim 38 where said  
2 plurality comprises k feed waveguides and k reflectors, and  
3 the angular extent of each said reflector about said  
4 central axis is  $360/k$  degrees.

5  
6           52) The power combiner of claim 38 where each said  
7 input waveguide is coupled to a source of asymmetric  
8 traveling wave power, said input power traveling through  
9 each feed waveguide, reflecting from said reflector and  
10 collected in said final waveguide.